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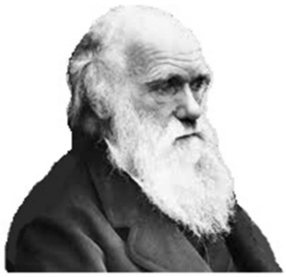

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# A Study of Land Cover Change Detection in Oddusuddan DS Division of Mullaitivu District in Sri Lanka Based on GIS and RS Technology

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**ABSTRACT**

Land cover change analysis between 1997 and 2016 was conducted in Oddusuddan Divisional Secretariat, Mullaitivu District, using remote sensing and geographic information system incorporated with field verifications. Various Satellite images and different digital maps have been used for extracting information. The overall objective of this study was to detect the magnitude of land cover change in Oddusuddan between 1997 and 2016. The methodology of this study was a change detection analysis of satellite imagery with Landsat ETM data. Two dates of Landsat image data of the 1997 and 2016 were used to produce a land cover map. The Maximum Likelihood algorithm was used for supervised classification to detect changes for twenty years. The result showed that during the last twenty years, the forest cover declined from 453.02 km$^2$ in 1997 to 447.14 km$^2$ in 2016. It was noticed that socio-economic factors were the major driving forces for the land cover change.

***Keywords*:** Change detection, Change Matrix, Geographical Information System & Remote Sensing, Land covers Mapping, Satellite Image Analysis

## 1. INTRODUCTION

Land cover change is mainly driven by natural phenomena and anthropogenic activities which would impact a natural ecosystem. A well-established land cover and land use management can be driven through understanding pattern, change, and interaction between human activities and natural phenomena. Today, data-driven from satellite images are suitable

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for land-cover change detection studies. The primary purpose of using remote sensing-based change detection is to monitor land cover change very effectively and efficiently. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Remote sensing-based change detection applies comparison of a set of temporal images covering the period of interest using specific change detection algorithms (Yismaw, Gedif, Addisu, and Zewudu, 2014). Land cover degradation is a key issue all over the world which induces temporary and permanent deterioration of structure of vegetation that directly affects species composition and diversity (Grainger, 2009). Monitoring land cover change through time is important for many applications such as land cover planning and management, climate change studies, wildlife conservation (Coops and Catling, 1997; Zimble *et al*., 2003). Traditionally, land cover mapping was done by using interpretation of aerial photograph and ground-based sample. This method is relatively time consuming and costly. Over the past decades, development of remote sensing technology provides a more automatic and efficient way of collecting data and managing land cover and land use (Yu, 2007). Satellite data have been used in land use and land cover mapping since 1970 (Broich et al., 2011). Different satellite images are used for land cover mapping. However, Landsat Thematic Mapper (TM) imagery is used for mapping of large area of land use and land cover (Dorren, Maier, and Seijmonsbergen, 2003).

There is no adequate information about the land cover of the Oddusuddan DS division. However, some works are carried out to provide information on forest cover of the DS division. Moreover, land cover change is a problem in the study area. However, the rate and aerial extent of land cover change have not been studied till date. Therefore, it is necessary to study land cover change on broad spatial and temporal scales for sustainable land management. The overall objective of this study was to detect the magnitude of land cover change. The specific objectives include identifying forest cover, and its spatial distribution, analysing the spatial and temporal change, creating land use, and land cover map of the study area for the years 1997 and 2016 and to assess the cause of land use and land cover change in the study area.

## 2. LITERATURE REVIEW

According to the recent research, the primary reasons for the degradation of forest cover are population pressure, the practice of agricultural methods, and lack of awareness about land use and forest cover. Assessment of the land use and land cover in any terrain should be taken into account with the following essential factors such as the rate of depletion, the reason for the deterioration, and remedial measures to restore. The assessment of land use and land cover change is not an easy task. It takes time to perform the assessment. It can be made more accessible only through Geographical information system and Remote Sensing techniques. Change detection and monitoring activities can be performed effectively by utilising remote sensing technology (Yismaw, 2014). The major four aspects of change detection are detecting the changes, identifying the nature of change, measuring the aerial extent of change and assessing the spatial pattern of change. These aspects will be considered in remote sensing as well (Mcleod and Conglton, 1998).

Over the past couple of decades, many types of research applied satellite images to detect land use and land cover change. For instance, look into (Unni, Roy, and Parthtasarathy, 1985), (Luque, 2000), (Imbernon and Branthomme, 2001), (Young and Wang, 2001), (Karia, Porwal, Roy, and Sandhya, 2001), (Boyd, Foody, and Ripple, 2002), (Larsson, 2002), (Roy and

Joshi, 2010), (Reis and Yomralioglu, 2006), (Panigrahy, Kale, Dutta, Mishra, and Banerjee, 2010), (Sakthivel *et al*., 2010), (Forkuo and Frimpong, 2012), (Yismaw *et al*., 2014), (Kayet and Pathak, 2015), (Sajjad *et al*., 2015), (Sadeghi, Malekian, and Khodakarami, 2017), (Mihai, Săvulescu, Rujoiu-Mare, and Nistor, 2017). The basic principle of change detection through remote sensing is that the changes in spectral signatures commensurate with the change in land use and land cover. The temporal impacts can be measured through process of change detection (O'Callaghan, 2012). The change detection is *the process of identifying differences in the state of an object or phenomenon by observing it at different times (multi-temporal variations)* (Singh, 1989). Change detection can be done precisely as GIS technology has high volume of special data handling capacity. In addition, GIS technology helps us to do overlay process with multi layers.

## 3. METHODOLOGY

For the change detection over a period of time, it is essential to have temporal satellite imagery of the same time period and same season. Landsat 5 and Landsat 8 Satellite images of two time periods, i.e. 1997 and 2016, with the general resolution of 30 m were downloaded from United State of Geological Survey website. In addition, 1:50,000 topographic maps were used for accuracy assessment of the images and geometric correction. A field survey was conducted for selecting control points. ERDAS Imagine 15 and ArcGIS 10.3.1 were used for image processing and land cover change detection. Image processing techniques were applied to make the images for a visual explanation of land cover (**Table 1**). These included geometric correction, radiometric correction, resampling images and clipping of the images. Both, unsupervised and supervised image classification techniques were applied. The unsupervised classification was done before fieldwork. For the supervised image classification training areas were established based on the ground truth taken during fieldwork. Among different algorithms in the supervised classification, maximum likelihood classification was utilised.

**Table 1.** Details of Land use/Land cover classification

| Land use/Land cover types | Details |
|---|---|
| Vegetation cover | It represents natural and fragmented forest cover areas including small trees, bushes, shrubs, small size plant species with fewer crowns |
| Agricultural area | The land that is covered with agricultural activities |
| Bare Land | The area with bare ground and degraded grassland |
| Waterbody | The Land completely occupied with water |

After the image classification, land use and land cover change were detected by identifying land cover types by using ERDAS Imagine 15 and ArcGis 10.3.1. With the help of visual interpretation of satellite images, four types of land covers are identified such as vegetation cover, settlement and Agricultural area, bare land and water body. Descriptions of each land cover are as follows (**Figure 1**).

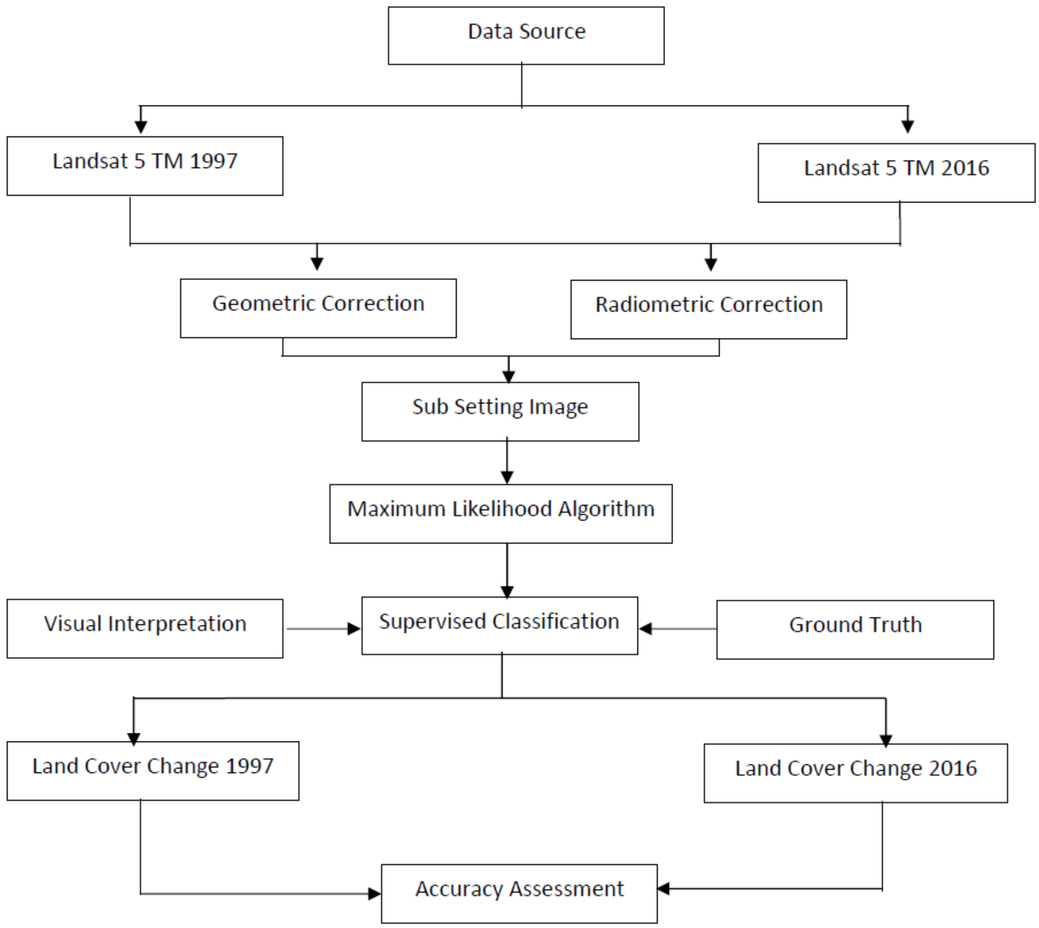


**Figure 1.** Flow chart of the methodology for land use/ land cover change

**Table 2.** Geospatial data used for change detection analysis of land use and land cover in Oddusuddan Divisional Secretariat (in 1997 and 2016)

| Datasets | Landsat scene ID | Scale/ Resolution (m) | Year | Data Source |
|---|---|---|---|---|
| Landsat 5 TM | LT51410541997022BKT01 | 30 m | 1997 | US Geological Survey, Earth Explorer |
| Landsat 5 TM | LT51410542016082BKT00 | 30 m | 2016 | US Geological Survey, Earth Explorer |

Multi-temporal data sets have been used to differentiate areas of land cover change between the dates of selected satellite images (**Table 2**). The change detection technique should be able to support to identify where and how much change has occurred. Further, the change detection matrix has been prepared to observe the trends and patterns of land cover change within a particular period. Kappa statistic was prepared for the different areas that were classified.

### 3. 1. Study area

The study area (Oddusuddan Divisional Secretariat-DS) is located in Mullaitivu District, Northern Province Sri Lanka. Oddusuddan lies between the North latitudes 9º03' and 9º24' and east longitude 80º20' and 80º45' (**Figure 2**). The total population of the area is 15,721 persons and the population density is about 24.19 per square kilometer (Department of Census and Statistics, 2012). The area consists of different types of land use and land cover. The study area was selected as a representative site of the entire Mullaitivu District. The selection of this study area is strongly related to the variety of natural environment and land use and land cover types.

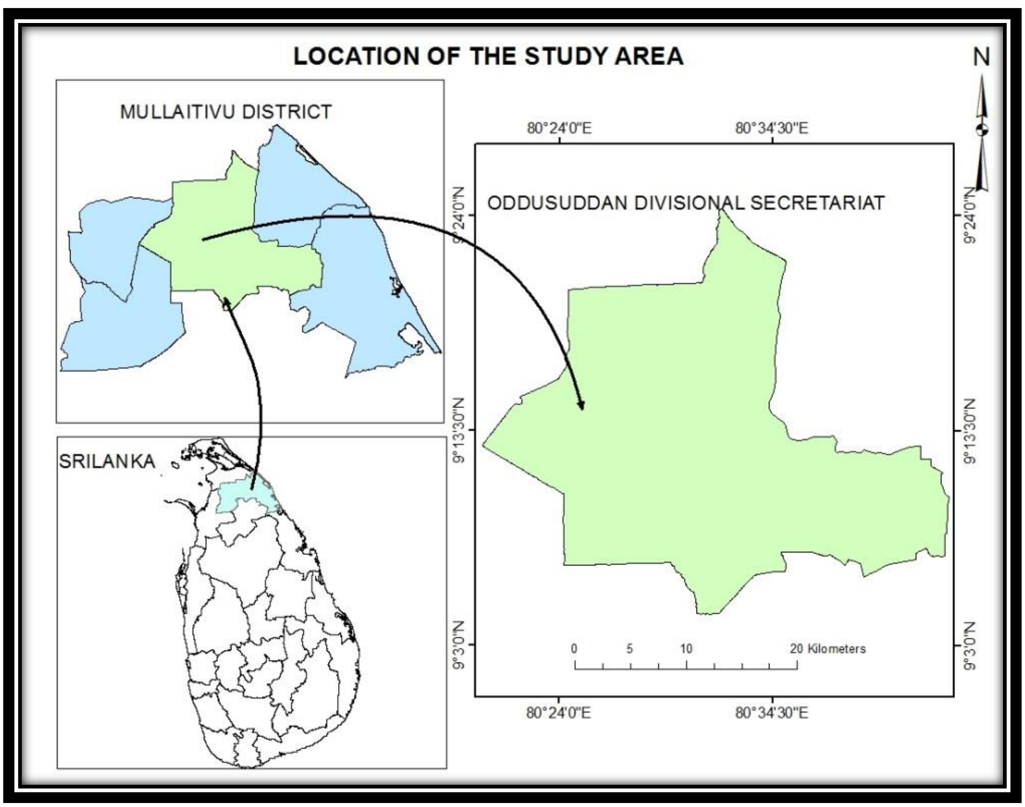


**Figure 2.** Location of the Study Area

## 4. RESULT AND DISCUSSION

Land use and land cover change in the study area from 1997 to 2016 is discussed in this section. Important changes in land use are found after applying the classification techniques on all satellite imageries. The map of land use classification is given for 1997 and 2016 (**Figure 3**). Pixel grid cell process was adopted to estimate land-use zones and land-use area. Supervised classification of the 1997 and 2016 Landsat TM images are shown in the following figures.

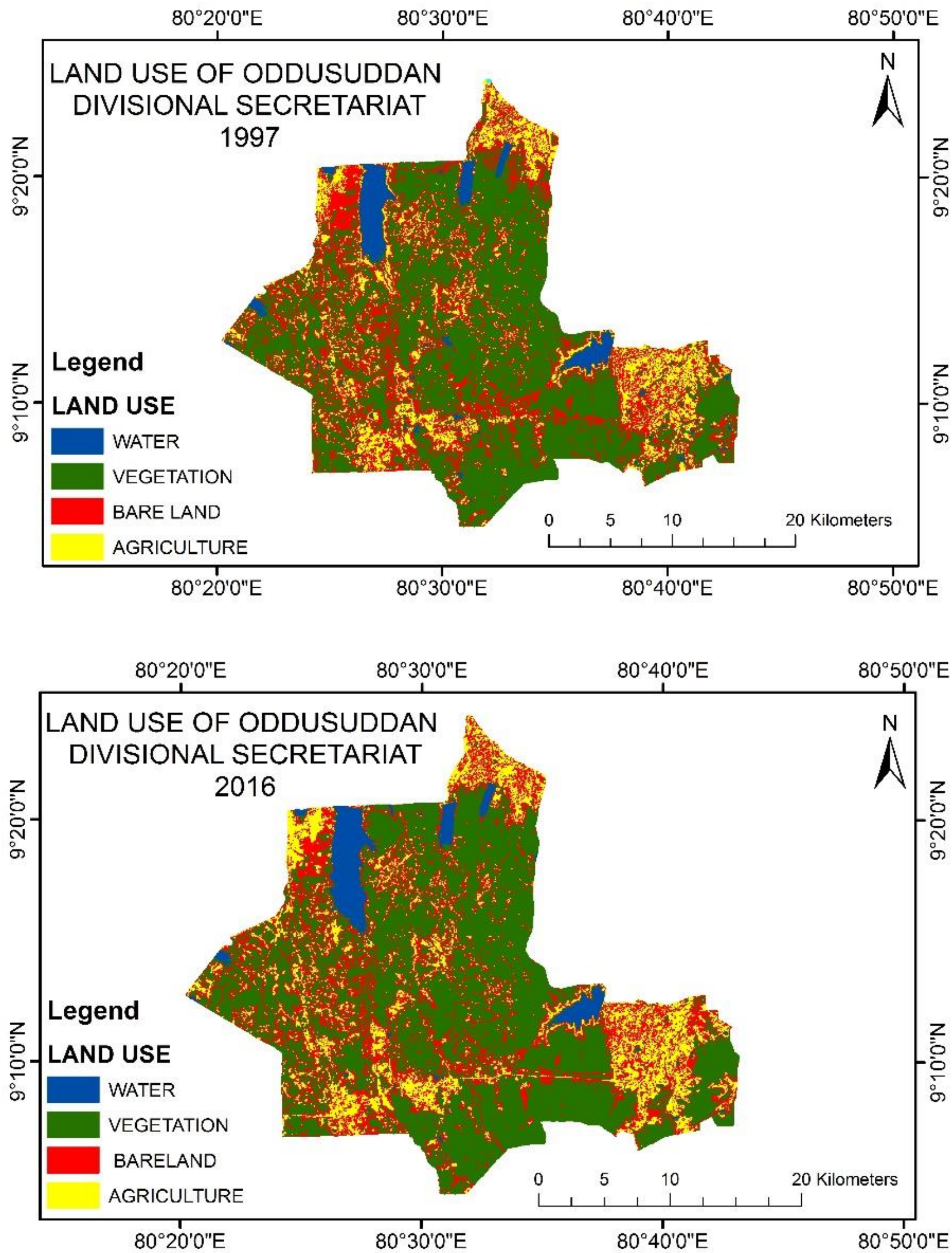


**Figure 3.** Land use/ Land cover classification of Oddusuddan DS Division in 1997 and 2016

### 3. 1. Change detection

Figure 3 shows the spatial distribution of land use and land cover in 1997 and 2016. In 1997, Vegetation covered 453.02 km$^2$ which is about 62.25% of the total study area. 136.16 km$^2$ is occupied by agricultural activity which is about 18.71% of the total area. 107.24 km$^2$ is under Bare Land which occupies about 14.74% of the study area. Waterbody constituted 31.28 km$^2$, that is 4.30% of the total area of the study area.

In 2016, vegetation occupied 447.14 km$^2$, representing 61.45% of the total study area. Similarly, agricultural activity covers a land area of 140.91 km$^2$ which is about 19.36% of the total area. The area of bare land constituted 106.42 km$^2$, representing 14.62% of the total land area. Waterbody has an area of 33.21 km$^2$ (representing 4.56%).

The supervised classification procedures applied to 1997 and the 2016 Landsat TM images. It is evident that vegetation is the dominant land use, 62.25% in 1997 and 61.45% in 2016, and followed by agricultural activity, bare land, and water body, respectively.

### 3. 2. Accuracy Assessment Using Error Matrix for Classified Images of the Year 1997 and 2016

It is very important to perform an accurate assessment of the classified images. The quality of a map from satellite imageries is determined by its accuracy. Accuracy assessment was done in 1997, and 2016 Landsat TM imageries and an assessment report were obtained having an error matrix, accuracy totals, and kappa statistics (as in **Table 3**). The Error Matrix was calculated to understand the accuracy of classification for the year 1997 and 2016. The error matrix is calculated on pixel by pixel basis. The pixels were converted to percentage. Overall classification accuracy of 88.12% and 85.62% and a Kappa coefficient (overall kappa statistics) of 0.8477 and 0.817097 was achieved in 1997and 2016, respectively.

**Table 3.** Summary of accuracy (%) and kappa statistics

| Land use/ Landcover | Producers Accuracy | | Users Accuracy | |
|---|---|---|---|---|
| | 1997 | 2016 | 1997 | 2016 |
| WATER BODY | 82.5 | 77.5 | 80.1 | 75.2 |
| VEGETATION | 90 | 82.5 | 88.9 | 81.5 |
| AGRICULTURE | 95 | 90 | 94.3 | 89.3 |
| BARE LAND | 85 | 92.5 | 83.9 | 91.3 |
| | | | | |
| | 1997 | 2016 | | |
| Overall Classification Accuracy | 88.12% | 85.62% | | |
| Overall Kappa Statistics | 0.8477 | 0.817097 | | |

Change conversion matrix for the years 1997 and 2016 is prepared to clearly understand the major source of land cover change. Change matrix for classified images of the year 1997 and 2016 has been produced and presented in Table 3. The matrix table depicts the areal distribution of each land cover that has experienced transformation from one type to another or remained the same (**Figures 4**).

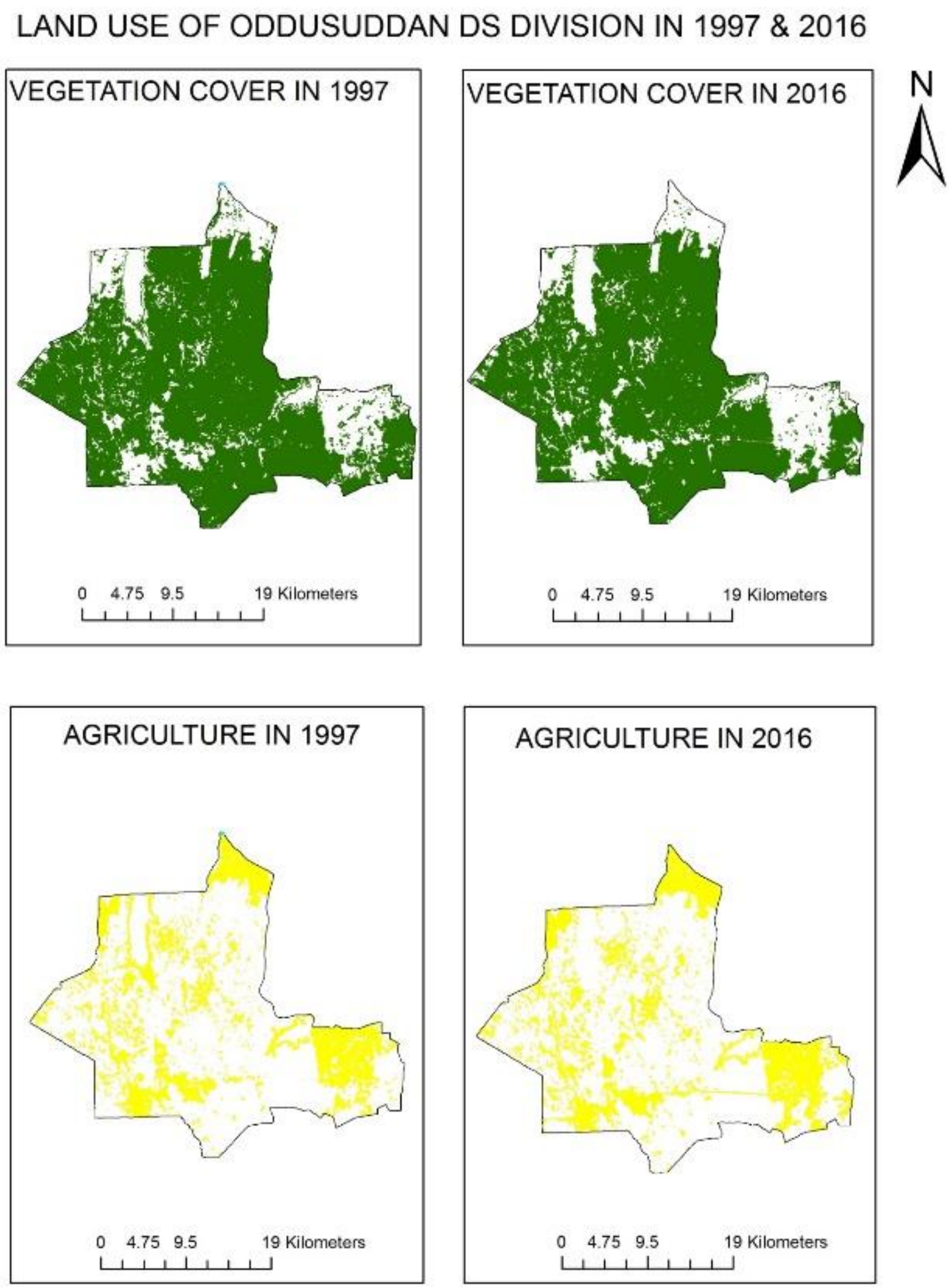


**Figure 4** (a-d)**.** Land used for vegetation, agriculture, Bare Land and Water bodies in Oddusuddan in 1997 and 2016

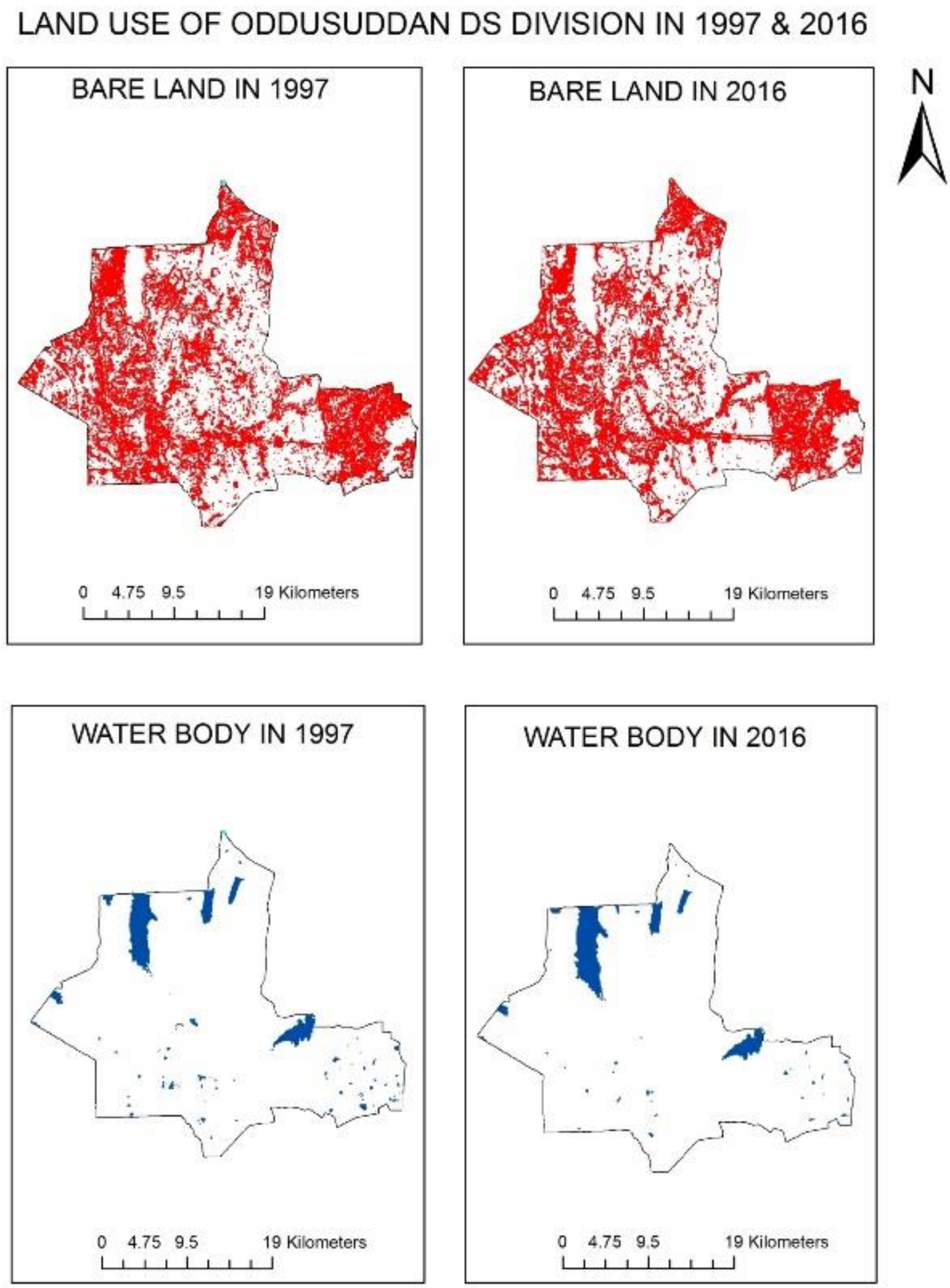


**Figure 4** (e-h)**.** Land used for vegetation, agriculture, Bare Land and Water bodies in Oddusuddan in 1997 and 2016

### 3. 3. The extent and rate of land cover/ land-use change

The extent and rate of land cover and land-use change is being monitored by using two Landsat TM images of 1997, and 2016. The total area of the land cover and land use in square kilometre and its percentage for each date of satellite images was calculated through digital image interpretation. Summary of total land cover and land use of 1997 and 2016 is given in **Tables 4** and **5**.

**Table 4.** Land use cover changes from 1997 to 2016

| LAND USE | 1997 | | 2016 | |
|---|---|---|---|---|
| | AREA (km²) | % | AREA (km²) | % |
| WATER | 31.28 | 4.30 | 33.21 | 4.56 |
| VEGETATION | 453.02 | 62.25 | 447.14 | 61.45 |
| AGRICULTURE | 136.16 | 18.71 | 140.91 | 19.36 |
| BARE LAND | 107.24 | 14.74 | 106.42 | 14.62 |
| TOTAL | 727.69 | 100.00 | 727.69 | 100.00 |

Based on this result, vegetation covered about 453.02 km² and 447.14 km² of the area in 1997 and 2016, respectively. 62.25% of the total area was covered with vegetation in 1997 that decreased to 61.45% in 2016. The rate of vegetation cover change is –0.29 km² per year between 1997 and 2016. The rate of vegetation cover change between 1997 and 2016 is given in Table 5.

**Table 5.** The rate of Land use/land covers change

| LAND USE | 1997 | 2016 | AREA CHANGED in km² (1997-2016) | CHANGE PER YEAR (km²) |
|---|---|---|---|---|
| | AREA (km²) | AREA (km²) | | |
| WATER | 31.28 | 33.21 | 1.94 | 0.10 |
| VEGETATION | 453.02 | 447.14 | –5.88 | –0.29 |
| AGRICULTURE | 136.16 | 140.91 | 4.75 | 0.24 |
| BARE LAND | 107.24 | 106.42 | –0.81 | –0.04 |
| TOTAL | 727.69 | 727.69 | 0 | 0 |

### 3. 5. The pattern of land use and land cover change

An error Matrix was prepared to understand land encroachment for different land categories from 1997 to 2016. The pattern of land-use change into other land-use type is presented in the following **Table 6**.

**Table 6.** Error Matrix of Land Cover/Land Use Changes from 1997 to 2016

| LAND USE in 2016 ($km^2$) | | LAND USE in 1997 ($km^2$) | | | | |
|---|---|---|---|---|---|---|
| | | WATER | VEGETATION | AGRICULTURE | BARE LAND | GRAND TOTAL |
| | WATER | 27.79 | 0.92 | 0.72 | 3.79 | 33.21 |
| | VEGETATION | 2.16 | 422.67 | 21.48 | 0.84 | 447.14 |
| | AGRICULTUR | 0.58 | 22.81 | 90.81 | 26.71 | 140.91 |
| | BARE LAND | 0.75 | 6.63 | 23.15 | 75.90 | 106.42 |
| | GRANT TOTAL | 31.28 | 453.02 | 136.16 | 107.24 | 727.69 |

About 2.16% area of water has been converted into vegetation, 0.58% into agriculture and 0.75% into bare land. About 0.92% area of vegetation covered has been transformed into water. 22.81 $km^2$ area of vegetation is converted into agriculture, and 6.63% area of vegetation is converted into bare land. Nearly 0.72% area of agricultural land has been transformed into the water body, 21.48% into vegetation, and 23.15% into bare land. About 3.79% area of bare land is converted into water bodies, 0.84% into vegetation, and 26.71% into agriculture. Areas of 27.79 $km^2$, 422.67 $km^2$, 90.81 $km^2$, and 75.90 $km^2$ classified as water, vegetation, agriculture, and bare land, respectively, remain unchanged from 1997 to 2016.

## 4. CONCLUSIONS

The land cover and land use changes have been investigated. Various thematic maps have been produced to illustrate the land cover and land-use change between 1997 and 2016. The identified main land use types in the study area are water, vegetation, agriculture, and bare land. The study indicates that a remarkable change on vegetation cover has occurred from 1997 to 2016. Anthropogenic activities induced a decrease in vegetation in the study area, but this was not discussed in this research. Hence, further studies could be carry out to better explain the impacts of anthropogenic factors on vegetation cover change.

The vegetation cover decreased by 5.88 $km^2$ between 1997 and 2016 in the study area. About 453.02 $km^2$ of the land was covered with vegetation of the total area of the Oddusuddan DS division in 1997. However, this figure declined to 447.14 $km^2$ in the year 2016. The high demand for agriculture land is directly linked with changes of vegetation cover in Oddusuddan

DS division. For the conservation of the vegetation cover from the further destruction, farmers should be encouraged to participate in the land use and the land cover management to create awareness as to maximum utilisation of resources in a sustainable manner.

Hence, to preserve the forest resources from further destruction and to use the forest resources in a sustainable manner, farmers should be encouraged to plant fast-growing trees on their farm boundaries, homesteads or on degraded lands instead of cutting trees from the existing land cover, introduce the fuel-saving stoves instead of using fuelwood in traditional three-stone stoves. Creating awareness among the society regarding optimum utilisation of the land cover recourses and conservation systems by concerned bodies could play a significant role in rehabilitation and minimising of environmental degradation.

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